Geology, Geochemistry, and Geophysics of Sedimentary-Hosted Au Deposits in P.R. China

Stephen G. Peters, editor

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GEOLOGY, GEOCHEMISTRY, and GEOPHYSICS of SEDIMENTARY ROCK-HOSTED Au DEPOSITS in P.R. CHINA

Stephen G. Peters (editor)

Summary

This report is the second report concerning results of a joint project and Annex Agreement between the U.S. Geological Survey and the Tianjin Geological Academy to study sedimentary rock-hosted Au deposits in P.R. China and in Nevada, USA. The Project has involved three joint field visits to deposits in China in 1997, 1999, and 2000 to 18 Chinese deposits and one visit to Nevada in 1999. Sedimentary rock-hosted Au deposits in China are important, because a number of deposits, such as the Lannigou Au deposit in the Dian-Qian-Gui area, contains >100 tonne Au resources. Many of the deposits are of medium size ~50 tonne Au resources and most have extensive exploration potential. In the Middle-Lower Yangtze River area, there are over 250 gossan Au occurrences in oxidation zones above sulfide-deposits. Since the 1980s, Chinese geologists have devoted a large-scale exploration and research effort to the deposits. As a result, there are more than 20 million oz of proven Au reserves in sedimentary rock-hosted Au deposits in P.R. China. Additional estimated and inferred resources are present in over 160 deposits and occurrences, which are under-going exploration. This makes China second to Nevada in contained ounces of Au in Carlin-type deposits. It is likely that many of the Carlin-type Au ore districts in China, when fully developed, could have resource potential comparable to the multi 1000 tonne Au resources in northern Nevada.

The six chapters of this report describe sedimentary rock-hosted Au deposits that were visited and also provide descriptions that were compiled from the literature in China in three main areas: the Dian-Qian-Gui, the Qinling fold belt, and Middle-Lower Yangtze River areas. Two introductory chapters provide an over view of sedimentary rock-hosted Au deposits and Carlin-type Au deposits and also provide a working classification for the sedimentary rock-hosted Au deposits. A final chapter contains a weights-of-evidence, GIS-based mineral assessment of sedimentary rock-hosted Au deposits in the Qinling fold belt and Dian-Qian-Gui areas. Appendices contain scanned aeromagnetic (Appendix I) and gravity (Appendix II) geophysical maps of south and central China. Data tables of the deposits (Appendix III) also are available elsewhere as an interactive database at http://geopubs.wr.usgs.gov/open-file/of98-466/. Geochemical analysis of ore samples from the deposits visited are contained in Appendix IV.

Chapters 1 and 2 provide a classification and summary of Chinese sedimentary rock-hosted Au deposits that mainly are located along the margins of the Precambrian Yangtze craton in the Qinling fold belt area in the north and northwest, the Dian-Qian-Gui area in the southwest, and the Middle-Lower Yangtze River area in the east. Distribution of the deposits is controlled by regional-scale rifts, district-scale short-axial anticlines (domes), deposit-scale high-angle

faults, stratabound breccia bodies, and unconformity surfaces. The deposits are hosted in Paleozoic to lower Mesozoic sedimentary rocks composed mainly of impure limestone, siltstone, and argillite. Alteration types mainly are silicification, decalcification, argillization, and carbonization. Igneous rocks usually are not present near most Chinese deposits. However, the Middle-Lower Yangtze River area contains pluton-related polymetallic replacement Au deposits.

Main types of sedimentary rock-hosted deposits in China are Carlin-type, pluton-related, syndeformational, unconformity-hosted, and red earth and laterite Au deposits. Gold is present as disseminations in most deposits, although local massive accumulations of Au-bearing sulfide are present, especially in mantos in the Middle-Lower Yangtze River area. The main opaque ore-bearing minerals include Au, electrum, pyrite, arsenopyrite, stibnite, orpiment, realgar, and cinnabar. Gangue minerals are quartz, barite, organic carbon, carbonate and clay minerals, and local albite. Geochemical elements associated with Au in Nevada deposits, such as As, Sb, Tl, and Hg, also are closely associated with many Chinese deposits, but U, Sr, W, and some PGE elements also are associated with some Chinese Au deposits. Stable isotopic data from deposits in China and Nevada suggest possible multiple fluid sources as indicated by interpretation of δD vs. $\delta^{18}O$, $\delta^{13}C$ vs. $\delta^{18}O$ and $\delta^{34}S$ data plots.

Chapter 3 describes deposits in the Dian-Qian-Gui area in southwest China associated with deposits of coal, Sb, Barite, and Hg. Most of the Au deposits are stratabound or structurally controlled, disseminated deposits commonly associated with structural domes. Deposits described are the Zimudang, Lannigou, Banqi, Yata, Getang, Sixianchang (Au–Hg), Jinya, Gaolong, Gedang, Jinba, and Hengxian Au deposits. Typical deposit characteristics include impure calcareous and carbonaceous host rock that contains disseminated pyrite, marcasite, and arsenopyrite with micron-sized Au in As-rich pyrite and realgar, orpiment, stibnite, and Hg-minerals, as well as minor base-metal sulfide minerals and elevated concentrations of As, Sb, Hg, Tl, and Ba. General lack of igneous rocks in the Dian-Qian-Gui area implies non pluton-related ore forming processes related to metal sources in carbonaceous parts of the sedimentary pile. Genetic processes that formed and mobilized petroleum and Hg may also be related to As-, Au-, and Tl-bearing coal horizons. Other Au deposits contain textures and features that indicate a strong structural control by tectonic domes or shear zones and suggest local syndeformational ore deposition possibly related to the Youjiang fault system. Several sedimentary rock-hosted Au deposits in the Dian-Qian-Gui area also are of the red earth-type (laterite-hosted) and have been concentrated and enhanced by the processes of deep weathering.

Chapter 4 describes Au deposits in the Qinling fold belt in central China, which is a long-lived mobile belt between the Huabei (North China) and Yangtze Precambrian cratons. The Qinling fold belt contains several groups of stratabound and tectonized sedimentary rock-hosted Au deposits in deformed or folded late Paleozoic to early Mesozoic sedimentary and volcanoclastic rocks in an east-west-elongated area approximately 750 km long and about 200 km wide. Deposits described in the East Qinling fold belt along the Ding-Ma Au belt are the Jinlongshan (Zhenan) Au deposit, as well as syndeformational Au deposits at Maanqiao, Baguamiao, and Shuangwang. Deposits in the West Qinling fold belt, associated with the Snow Mountain fault, also are described at Songpangou, Qiaoqiaoshang, and Dongbeizhai. Other deposits are described at Liba, Yinchanggou, Lianhechun, Laerma (Au–U), Manaoke (Au–W), and along the Luhuo-Daofu fault zone at Pulongba and Qiuluo. Sedimentary lithofacies in the Qinling fold belt contain low metamorphic grade calcareous sandstone, chert, siltstone, interbedded micritic limestone, carbonaceous and calcareous slate, and local mafic units.

Magmatic activity was widespread in the Qinling fold belt area and resulted in the emplacement of Paleozoic and Mesozoic geochemically intermediate composition stocks and plutons. Igneous rocks are not specifically exposed in or associated with most of the sedimentary rock-hosted Au deposits, although the Liba deposit has many pluton-related geochemical characteristics. Some minerals not normally common to Carlin-type sedimentary rock-hosted gold deposits locally are present in some deposits in the Qinling fold belt, such as scheelite, uranium, and titanium minerals, as well as local albite.

Chapter 5 describes various Au deposits in the Middle-Lower Yangtze River area that contains several hundred sedimentary rock-hosted Cu, Fe, Au, S and polymetallic deposits and is part of one of the most important metallogenic belts in China. Early Paleozoic to early Mesozoic sedimentary rocks contain host horizons for Cu, Au, and polymetallic deposits, as well as Carlin-type, distal-disseminated sedimentary rock-hosted Au deposits, and red earth or laterite-hosted Au deposits. Gold porphyry deposits are also locally present. Stratabound replacement Au deposits are hosted in specific horizons in Triassic sedimentary rocks in southeastern Hubei Province in Tonglushan-Daye area, and in Upper Carboniferous silty limestone horizons in Anhui Province in the Tongling area. Local Carlin-type deposits in the Middle-Lower Yangtze River area, such as the Zhanghai Au deposit, are hosted in black Silurian phyllite and shale. The Au deposits are associated with 160 to 180 Ma diorites in the Tonglushan (Daye) area and 140 to 150 Ma porphyry plutons in the Jinhangshan-Fengshandong-Lijiawan area and 80 Ma stocks at the Jinjinzui porphyry Au deposit in southeast Hubei Province. In Anhui Province, most stratabound ores, such as at Tongguanshan, Xinqiao, Mashan, and Huangshilaoshan are associated with 137 to 153 Ma stocks. Red earth, or laterite-hosted deposits, are represented by the Shewushan Au deposit and are a product of supergene redistribution of Au.

Chapter 6 uses the weights-of-evidence method of mineral assessment to investigate the potential areas of undiscovered sedimentary rock-hosted Au deposits and occurrences in the Qinling and Dian-Qian-Gui areas of the P.R. of China. Preliminary modeling was performed based on Bayesian probability, to produce resource favorability maps from various geoscientific data, primarily geology and structure. Maps of favorability reveal numerous regional-scale exploration targets in the two regional-scale study areas where few, if any, known sedimentary rock-hosted Au deposits or occurrences exist. Modeling also indicates that the most important criterion for predicting sedimentary rock-hosted Au deposits and occurrences in both the Qinling and Dian-Qian-Gui areas, in order of importance, are geologic units, geologic unit-related factors (proximity to unit boundaries and lithodiversity), and structure-related factors (proximity to faults and topographic slope).

中国沉积岩金矿床地质、地球化学和地球物理

（总 结）

史蒂芬 G.彼得斯　　　黄佳展

本文是美国地质调查所与中国天津地质研究院合作研究中国和美国（内华达）沉积岩金矿床项目的第二份报告。该项目包括中美双方于 1997 年，1999 年和 2000 年对中国沉积岩金矿床进行的野外调查，1999 年对内华达沉积岩金矿床进行的野外调查，本报告 6 章中论述的滇黔桂地区、秦岭褶皱带和长江中下游地区的金矿床，有些我们调查研究过，另外一些选自中国的有关文献。前两章介绍了沉积岩金矿的分类。最后一章介绍运用权重法和地理信息系统 对秦岭褶皱带和滇黔桂地区的沉积岩金矿进行资源评估。附录 I 和 II 分别为中国中部和南部地区的航磁和重力扫描图，附录 III 的沉积岩金矿床一览表为交互式数据库，网址：http://geopubs.wr.usgs.gov/open-file/of98-466/附录 IV 为矿石样品的化学分析结果。

报告的第 1、2 章对中国沉积岩金矿床进行了分类和总结。中国沉积岩金矿床主要分布于西北地区秦岭褶皱带的扬子前寒武纪克拉通边缘，西南的滇黔桂地区以及东部的长江中下游地区。这些金矿床受区域性断裂、矿区规模的短轴背斜（穹隆）、矿床规模的高角度断层、层控角砾岩体和不断合面控制，主要产于古生代—中生代不纯灰岩、粉砂岩和泥岩中。蚀变类型有硅化、脱钙化、泥化和碳化，局部钠长岩化。除了煌斑岩和硅质岩脉外，沉积岩金矿床附近一般没有火成岩侵入体。但是长江中下游例外，产有与侵入岩有关的金矿床。

主要的金矿床类型有卡林型金矿床，与侵入体有关的金矿床、造山带的金矿床、不整合面的金矿床和红土型金矿床。在大多数沉积岩金矿床中，金主要呈浸染状产出，但在长江中下游地区局部金产在块状硫化物中，尤其是在层控平卧矿床中。不透明矿物有金矿、银金矿、黄铁矿、毒砂、辉锑矿、雄黄、雌

黄和毒砂、脉石矿物有石英、重晶石、有机碳、碳酸盐和粘土矿物，局部有钠长石。美国内华达州金矿床与 As，Sb，Tl 和 Hg 元素组合有关，中国许多沉积岩金矿床也与这些元素密切相关，而且U，Sr 和铂族元素也与一些金矿床有关。

第 3 章论述了中国西南滇黔桂地区金矿床。这些金矿床与煤，锑，重晶石和汞矿有密切的空间关系，且大多数金矿床为层控或构造控制的浸染状矿床，通常与构造穹隆有关。这类金矿床的典型特征是产于不纯的钙质和碳质岩矿中。这些沉积岩含有浸染状黄铁矿、白铁矿和毒砂 —其富砷边含微粒金。矿石中还有雄黄、雌黄、辉锑矿、汞矿和少量贱金属硫化矿。地球化学方面以 As，Sb，Hg 和 Ba 的含量升高为特征。

滇黔桂地区普遍缺失火成岩，表明该地区的成矿作用与侵入体无关。一些矿床的特征表明成矿的金属来源于沉积岩系的碳质岩石，该区的成矿组合可能是运移和形成石油及汞的成矿作用的产物，煤系地层中的 As，Au 和 Tl 也可能与这种成矿组合有关。另外一些金矿床的结构和明显受构造穹隆或剪切带控制的特征，表明同变形的矿石沉淀可能与右江裂谷系有关。该区几个沉积岩金矿床由于强烈的风化富集作用而形成红土型金矿。

第 4 章论述了秦岭褶皱带的沉积岩金矿床。秦岭褶皱带位于华北和扬子前寒武纪克拉通之间，呈西—北西走向，是一个长期活动带，含有几组层控和构造化的沉积岩金矿床，产于 EW 走向，长约 750 km，宽约 200 km 的晚古生代至早中生代已变形、褶皱的沉积岩和火山碎屑岩中。EW 向的褶皱带岩石为低级变质钙质砂岩、燧石、粉砂岩，以及互层的微晶灰岩、碳质和钙质板岩，局部有镁铁质火山岩。该带的岩浆活动普遍，形成许多古生代和中生代中性成分的岩株和侵入体的侵位。虽然李坝金矿床有许多与侵入体有关的地球化学特征，但是大多数沉积岩金矿床周围都没有见到火成岩出露，一些在卡林 型金矿床中不常见的矿物，如白钨矿，铀矿物和钛矿物出现在秦岭褶皱带的一些金矿床中，局部还有钠长石。

第 5 章论述长江中下游地区金矿床，该区有几百个沉积岩铜、铁、金、硫和多金属矿床，是中国最重要的金属成矿带之一。上古生界至下中生界沉积岩有多个铜、金和多金属矿含矿层，并产有卡林型金矿床、浸染状远源沉积岩金矿床和红土型金矿床。局部产有斑岩金矿床。层控交代型金矿床产于鄂东南铜录山—大冶地区的三叠系沉积岩和安徽铜陵地区上石炭系粉砂质灰岩中。局部地区卡林型金矿床如张海金矿床产于志留系黑色页岩和粉砂岩中。铜录山（大冶）地区的金矿床与 160～180 Ma 的闪长岩有关，鸡笼山—封山洞—李家湾地区的金矿床与 140～150 Ma 的斑岩有关，金井嘴斑岩金矿床与 80 Ma 的岩株有关。安徽铜陵地区大多数层控金矿床，如铜官山、新桥、马山和黄狮涝山等与 137～153 Ma 的岩株有关。以蛇屋山金矿床为代表的红土型金矿床是金的表生再富集的产物。

报告第 6 章运用矿产资源评估权重法，评估了中国秦岭褶皱带和滇黔桂地区未发现的沉积岩金矿资源潜力。根据 Bayesian 概率，综合各种地质数据，如地质和构造建立的成矿模式编制成矿预测图，在已知沉积岩金矿床寥寥无几 的上述两个研究区中圈出几个具区域规模的勘探靶区。该模式表明秦岭褶皱带和滇黔桂地区沉积岩金矿床预测的最重要标志依次为地层及与之有关的因素（靠近地层界线和岩性变化带）和构造有关因素（靠近断层和地形斜坡带）。

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